Planetary Instrument Concepts For The Advancement Of Solar System Observations

Frequency agile heterodyne detector for submillimeter spectroscopy of planets and comets

Completed Technology Project (2015 - 2018)

Project Introduction

The primary objective of this proposal is the development of a planetary THz heterodyne sensor for molecular line spectroscopy in space, based on transitions between quantum states in semiconductor quantum wells, and that can operate at physical temperatures of 50 K to 70 K. This would be a major advance for deep-space planetary and cometary missions. To date, all other THz heterodyne mixers (usually developed, for astrophysics applications) have utilized superconducting materials, and thus required cryogens or a mechanical cooler for operation near 4 K. Such systems cannot be flown for an extended period of time or require substantial cooling power and are unsuitable for planetary missions. State-of-the-art (SOA) heterodyne receiver technology intended for planetary instruments is based on Schottky-diodes operating at ambient temperature, typically below 1 THz. The only submillimeter heterodyne instrument that has flown to another planetary body is the Microwave Instrument for the Rosetta Orbiter (MIRO). MIRO has performed spectacularly on the cometary mission having determined the abundances of major gases, the surface outgassing rate and the nucleus subsurface temperature. However, it is based on decades-old mixer technology and its operating range was limited to two bands: 190 GHz (189-192) and 562 GHz (548-581), with high noise temperature ~ 8,000 K single-side band (SSB) in the 562 GHz band. The proposed Tunable Antenna-Coupled Intersubband Terahertz (TACIT) mixer will be a big leap forward for planetary science in the wide THz range, which is rich with many spectral lines. Besides the much greater number of gaseous species becoming accessible, a TACIT-based receiver will enable the study of winds with sufficient velocity resolution and permit high-sensitivity thermal imaging of surfaces. TACIT mixer absorbs THz radiation power resonantly, via a transition of electrons from the lower energy subband to the higher energy subband in a quantum well (QW) engineered AlGaAs/GaAs based material. Electric gates control the energy separation between subbands and thus provide the possibility to tune the mixer's frequency. After the radiation is absorbed the detector operates as a hot-electron bolometer (HEB). That is, the radiation power heats the electron gas and a large bolometric response is observed since the resistance has strong temperature dependence. This mixer will have several revolutionary technological advantages including: • low noise temperature (~ 2,000 K [SSB]); • low required local oscillator power (~ 20 microwatts); • operating temperature obtainable with passive radiative cooling in space (50-70 K); • very broad frequency range (1-5 THz) tunable electrically. Beside the spectral coverage, the 'breakthrough' TACIT mixer will: • enable sensitive array receivers thus tremendously increasing the volume of data returned over the life time of a mission; • be frequency re-programmable in flight so it can address questions or conditions not anticipated pre-launch. A TACIT-based THz spectroscopic receiver can be used on a number of the missions mentioned in the 'Vision and Voyages for Planetary Science in the Decade 2013-2022.' It is relevant to the numerous mission concepts, e.g., NASA's Europa mission, Journey to Enceladus and Titan, Enceladus Explorer, VESPER

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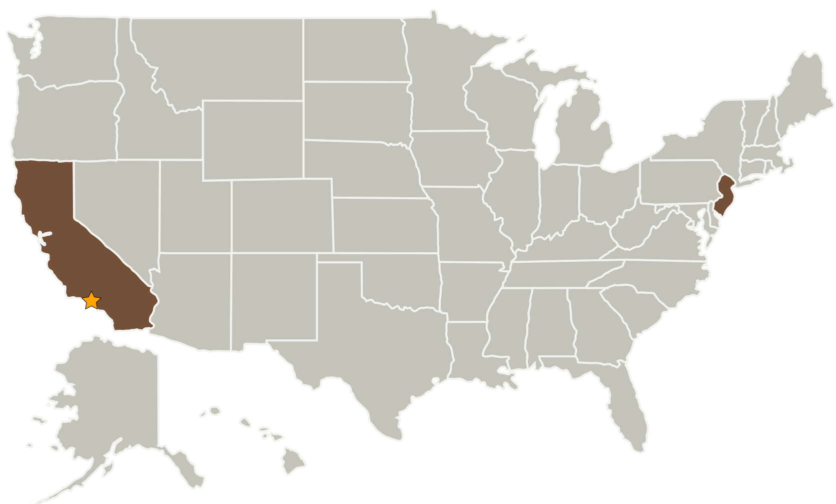
Table of Contents

(Venus), Martian Water Dynamics, Comet Explorer, Jupiter Icy Moons Explorer, Titan-Saturn System, Jupiter-Europa Orbiter, etc. In the proposed 3-year task we will optimize the material processing and the embedded THz antenna circuit, and will demonstrate a fully operational laboratory receiver. At entry, the TRL = 2, at the exit TRL = 4. The TACIT development effort is collaboration between the Jet Propulsion Laboratory and University of California Santa Barbara with contributions from Princeton University and LongWave Photonics LLC. This work builds on a recent 1-year PIDDP funded effort in 2013.

Anticipated Benefits

The results of this project will be used in various future planetary and cometary missions for composition and isotopic ratio analysis of gaseous species and wind velocity measurements in planet atmospheres. It will open the door into the previously unexplored terahertz part of the spectrum where many molecular transition lines reside.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Jet Propulsion Laboratory(JPL)	Lead Organization	NASA Center	Pasadena, California

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Center / Facility:

Jet Propulsion Laboratory (JPL)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

Project Management

Program Director:

Carolyn R Mercer

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Principal Investigator:

Boris S Karasik

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Samuel Gulkis
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Paolo Focardi
Mark Sherwin
Alan W Lee

Primary U.S. Work Locations	
California	New Jersey

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
    - └ TX08.1.1 Detectors and Focal Planes

Target Destination

Others Inside the Solar System